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Agricultural Memorandum No. 988

Use of meteorological data in plant disease warning schemes

by C P Roe

1. Introduction

The Agricultural section of the Meteorological Office has for a number of years provided to MAFF information on the occurrence of weather conditions conducive to the spread of certain plant diseases. The warning scheme began in 1975 with the introduction of the barley mildew criteria and has continued to expand up to the present complement of eight diseases.

Major changes in the system have resulted from the implementation of the combined plant disease program and these are described here. Background information on the diseases currently assessed is given together with the criteria used in the operational programs. Proposals for possible future developments are presented. It is intended that this memo will serve as a useful reference guide to colleagues in ADAS as well as in the Agro-meteorological discipline.

2. Plant diseases - background information

Work carried out in recent years by plant pathologists and agricultural meteorologists has identified several weather-plant disease relationships. It has been possible to define criteria for potential infection periods in terms of readily available meteorological variables. Combining this information with a knowledge of crop phenology, existing disease levels and carry-over from previous years, plant pathologists are in a position, for example, to advise on both the need for spraying and its timing to achieve optimum effect.

The following paragraphs give a brief description of the nature of the diseases currently assessed, and discusses those conditions likely to favour their spread.

Apple Scab

Apple scab is a fungal disease causing lesions on leaves and developing fruit which can become mis-shapen if heavily infected. The fungus overwinters on fallen leaves and infects apple trees during the spring, when buds are opening. The impact of raindrops on fallen leaves causes spores to be released which can infect new tree growth.

Barley Mildew

The most common and normally the most damaging disease of barley. It is a fungal disease, easily recognised by white mildew patches on the surface of leaves, which reduces their photosynthetic efficiency with consequent loss in grain yield. The disease is favoured by warm, dry conditions when sporulation occurs freely, the spread of spores being assisted by strong winds.

Eyespot

A disease of intensively grown cereals, particularly winter wheat. The eyespot fungus causes rotting at the base of the stem of the plant and may result in lodging, premature ripening and poorly filled ears, if not controlled effectively. Infection

is carried over on stubble for at least two seasons following an infected crop, and is spread by rainsplash. The fungus sporulates freely in mild damp weather and although most varieties of winter wheat grown in Britain have good resistance to the disease, fungicide application may still be necessary to check spreading.

Fireblight

Fireblight is a bacterial disease which attacks and often kills apple and pear trees and related trees and shrubs. Infection occurs initially in blossoms or soft, rapidly growing shoots which wilt, turn brown and die. The disease can then spread into larger branches and kill them, possibly killing the tree or shrub if infection reaches the main stem. Temperature, rainfall and sunshine play an important role in the development of the disease.

Net Blotch

A common, though rarely damaging disease of barley, except in the South West. The fungus is seed-borne and leaf infection is characterised by a short brown stripe, from which spores are produced to infect other leaves and adjacent plants. Researchers have found good evidence to suggest that debris from a previously infected crop are an important source of infection to subsequent crops. The spread and development of the disease is encouraged by wet weather.

Potato Blight

This is the most damaging disease of potatoes in Britain, reducing the total yield by killing foliage before a full crop of tubers has had chance to develop and by infecting tubers which then rot in the ground or in storage. The dependence of disease levels on weather has long been realised, and levels can vary greatly from year to year and from region to region. The Met Office has offered a warning scheme of critical periods since 1950 although more recently the introduction of a mathematical model of disease development has enhanced the accuracy of the information given.

Rhynchosporium

Rhynchosporium has been prevalent in this country since the 1960s when barley began being grown intensively in SW England. Today the disease can be found in all parts of Britain but particularly in south western parts and coastal districts elsewhere. In addition to barley, it is common on rye and some grasses.

Septoria

Septoria is a common disease of winter wheat, especially in the wetter western half of England and Wales where it can be a major limiting factor to the successful growing of winter wheat. In the arable areas of Eastern England it is only usually a problem in wet summers and perhaps some coastal areas.

3. Operational Programming Techniques

Scientists have managed to evaluate criteria for potential infection periods in terms of meteorological variables and those to be found in the combined plant disease message (see below) are shown in Appendix 1.

Computer programs incorporating these criteria have been written over a number of years, the first being for barley mildew back in 1975. The programs are normally run around mid-morning each day during the season of interest, accessing data for the previous twenty four hours which has been telexed into the Synoptic Data Bank from all over the country. Output from the programs is in the form of a telex message which is dispatched to the MAFF computer at Guildford around mid-day for subsequent access by

ADAS Plant Pathologists in each region. The data is also sent directly to the Plant Disease Intelligence Unit at Bristol for interpretation by plant pathologists (see Fig 1). Certain routine messages are similarly telexed direct from Bracknell to the East of Scotland College of Agriculture (ESCA) and to the Department of Agriculture, Northern Ireland.

The system is now described in more detail using the combined plant disease program as an example.

4. The Combined Plant Disease Program

Following the suggestion of ADAS plant pathologists a new plant disease message was introduced on 1 January 1983. The so-called HERDS program is aptly named because it herds together the most useful information from four existing messages into a more convenient form.

The reasons for its introduction are two-fold. Firstly thoughts began to turn towards producing a single compact message as the transmission of four daily telexes to MAFF became increasingly expensive. Secondly pathologists felt that much of the information provided in the existing messages was not essential to their daily activities. The "old" programs are still used today, the only change being that their outputs are no longer written to paper tape for transmission but rather to on-line datasets for access by HERDS.

The new program produces a daily table of meteorological data, disease indices and counts for 100 or so stations in the United Kingdom (see Appendix 2). A paper copy of the output is produced for local storage in addition to the telex output. Telex messages in the past were made through the medium of paper tape, the tape being manually fed into a teleprinter for onward transmission to recipients. Earlier this year, the "telex manager" system was adopted and being almost fully automated it no longer requires paper tape and keeps manual intervention to a minimum. Output from HERDS is copied to an on-line dataset which is then accessed by communications computers which direct the message into the telex manager for dispatch.

Fig 2 shows what steps are involved in producing a telex message; the diagram assumes a time of year when all four of the program outputs which go to make up the message are 'in-season'. The programs calculating the disease indices referred to in Fig 2 are described briefly below.

HEYES

The program accesses hourly temperatures and dew points from the Synoptic Data Bank and calculates an eyespot disease index. It is run daily on COSMOS over the disease season, normally 15 January to 30 June.

HAPPL

HAPPL incorporates modules to produce indices for apple scab, rhynchosporium, septoria and experimental criteria for net blotch. Hourly values of present weather, wind speed, temperature and dew points are needed in the calculations, which take place over the period 15 January to 31 July.

HAGRO

HAGRO was written to extract a wide range of weather variables for any number of stations, currently the same 100 or so stations that appear on HERDS. However, the program also includes modules for the Smith and Polley indices of barley mildew because it was much simpler, in terms of programming necessity, to modify an existing program rather than to write a complete program from scratch. HAGRO produces its own telex of met observations but the required items for HERDS are written off to a separate dataset.

Flow of weather information to Plant Disease Intelligence Unit

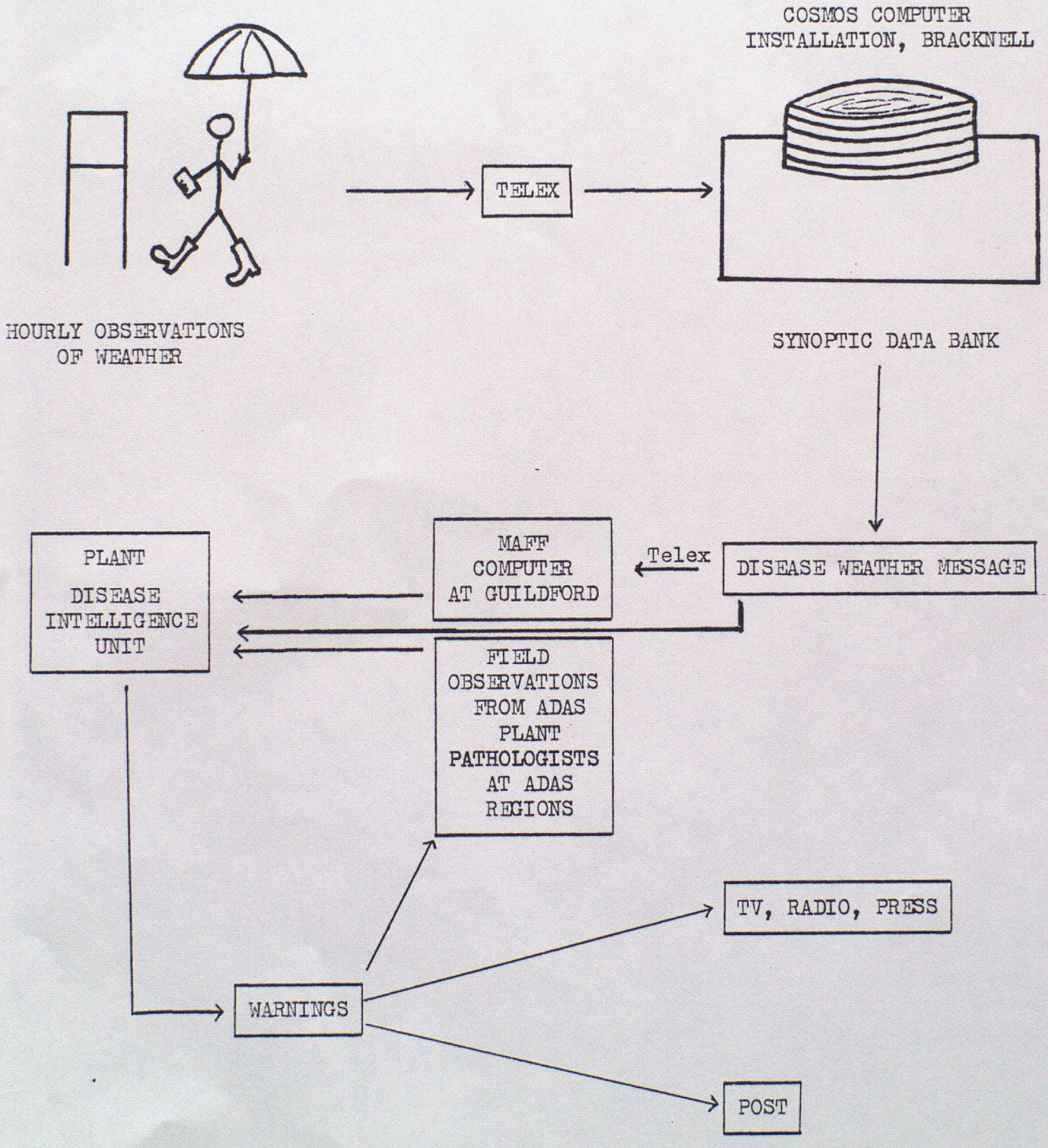
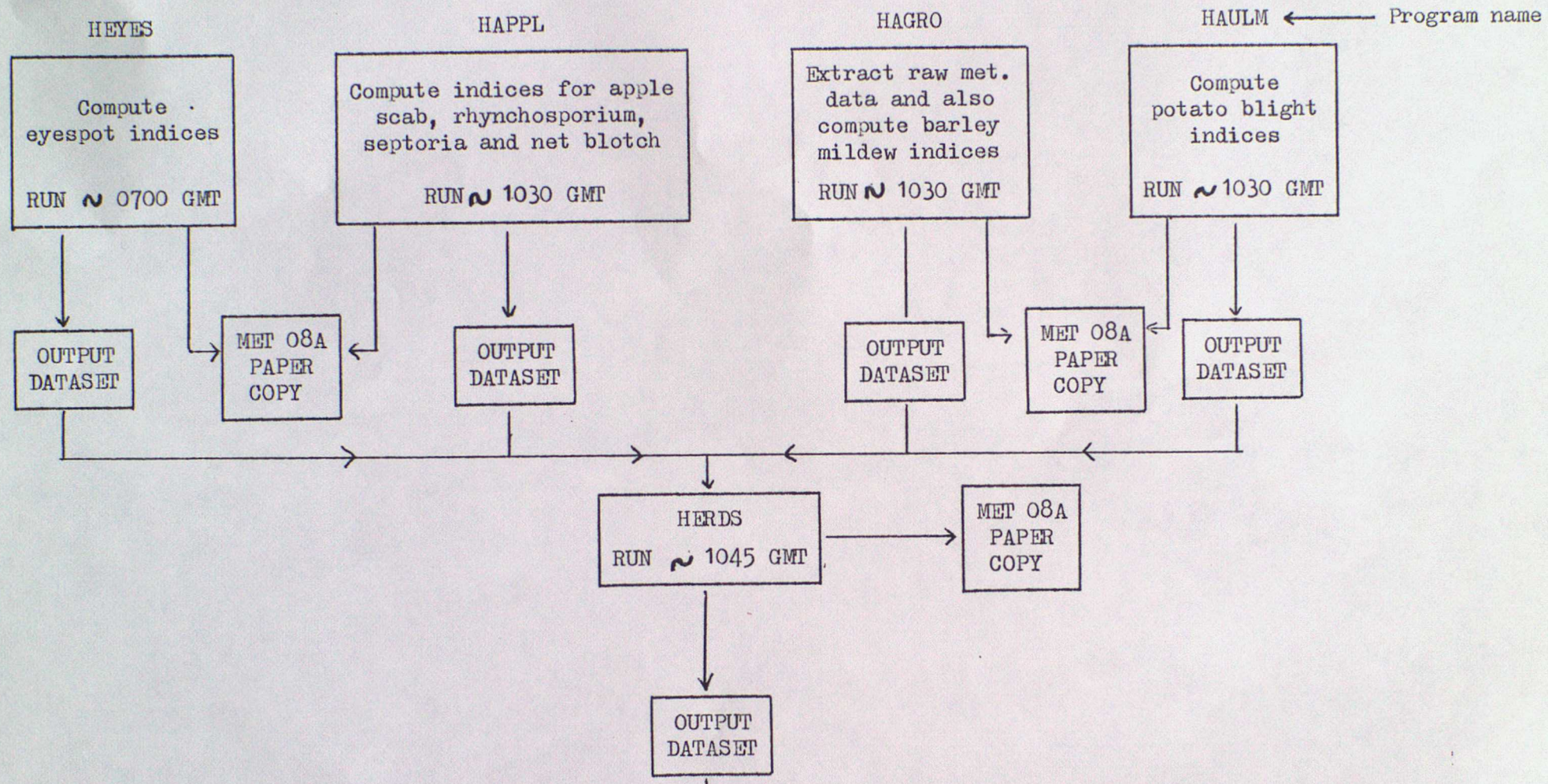


Fig 1

DAILY SEQUENCE OF EVENTS IN PRODUCING A HERDS TELEX MESSAGE



MESSAGE RECEIVED (AT ~ 1130 GMT) BY
1) MAFF PERSONNEL AT GUILDFORD & BRISTOL
2) EAST OF SCOTLAND COLLEGE OF AGRICULTURE
3) DEPARTMENT OF AGRICULTURE, NORTHERN IRELAND

NOTES

HEYES – Runs daily over the period 15 January to 30 June
HAPPL – Runs daily over the period 15 January to 31 July
HAGRO – Runs daily all year
HAULM – Runs daily over the period 15 May to 30 September

These timings are subject to alteration.
When 'out of season' a series of blanks will appear on the HERDS message under the headings for that particular disease.

Fig 2

A POSSIBLE ALTERNATIVE TO THE PRESENT AGRO-MET DATA SYSTEM

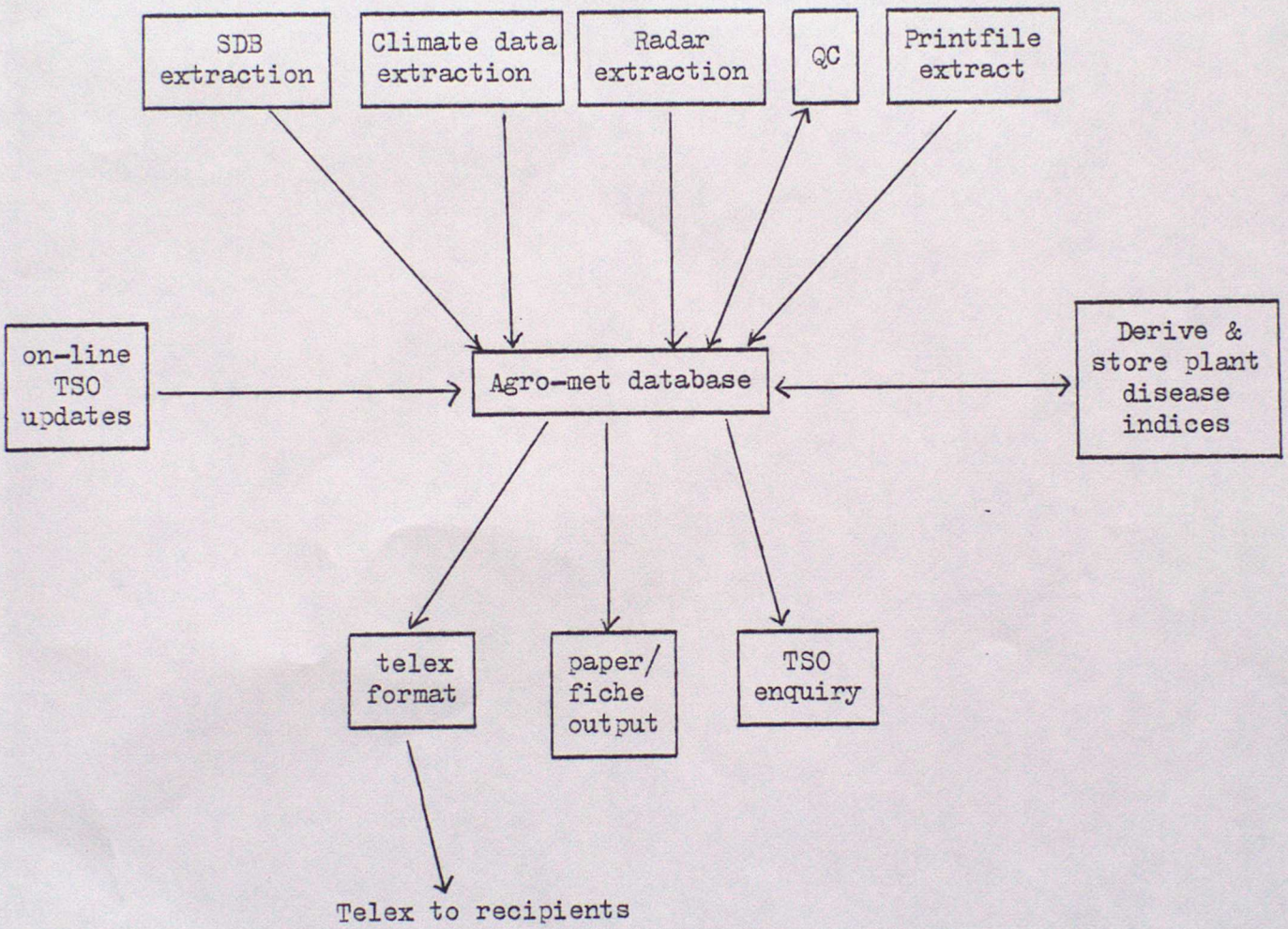


Fig 3

HAULM

The program is run daily over the period 15 May to 30 September and computes various potato blight indices of which only three are required by HERDS.

5. Future developments of the disease warning scheme

New applications for agro-met data are continually being found and it is apparent that the present system of writing individual programs to meet each new requirement is not the best way to satisfy the ever increasing demand for agro-met data. Taking the plant disease programs as an example, these were written over a number of years and can be run totally independent of each other. This has the disadvantage that large program segments (and often the ones requiring most frequent change) are repeated in many of the programs. Further, it is often easier, from a programmer's point of view, to write a completely new program rather than add a few additional statements to an existing program in order to compute a new index.

An improvement on the present system would be to adopt a "horizontal" program structure as illustrated in Fig 3. The central feature is a large agro-met database containing, for a given period, a combination of basic weather elements and derived parameters, such as the plant disease indices. Data is input to the database via a series of data extraction and parameter-deriving programs. Once filled, the data therein would be accessible by any number of specific programs, eg ones to produce a telex message, paper/fiche copy of data etc. The inherent advantages of this system are that changes can be made in one area without disturbing other areas, and new programs will only require the minimum of programming effort, using existing data extraction, telex formatter routines etc. This system however still has its limitations and a great deal more thought is required before it could be implemented.

A further improvement will come about from the siting of additional observing sites which should hopefully fill the large gaps in the network which exist at present in parts of Scotland and Wales. This might be seen as vital in hill farming areas where there is a scarcity of both the climataological information necessary for improving our understanding of the idiosyncrasies of hill climates and of the detailed synoptic data so necessary in these often marginally economic regions.

6. Conclusions

The advice offered by the meteorologist forms an essential link in the chain of producing a plant disease warning. The information is interpreted by plant pathologists aided by detailed field intelligence data.

Since the introduction of the first warning scheme for barley mildew back in 1975, agro-meteorologists have striven to increase the range and quality of the services they provide to the farming and horticultural community. This is reflected by the wide range of services now offered and by the increase in clientele who take advantage of them.

Major improvements in the system are likely in years to come so that the office will be in an even better position to provide a more comprehensive service to one of our most weather sensitive industries.

7. Acknowledgements

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Any comments or suggestions on this paper should be directed to the author.

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1 September 1983

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APPENDIX 1

CRITERIA USED IN PLANT DISEASE PROGRAMS

Apple Scab

A 'Smith period' defines a possible infection period as starting when precipitation is reported and continues while the criteria in Table 1 are satisfied.

Table 1

Mean hourly temperature during period °C	Hours with relative humidity ≥ 90% required for light infection	Mean hourly temperature during period °C	Hours with relative humidity ≥ 90% required for light infection
25.5	13	11.5	12
25.0	11	11.0	12
24.5	9.5	10.5	13
17.5-24.0	9	10.0	14
17.0	9	9.5	14.5
16.5	9	9.0	15
15.5	9.5	8.5	17
15.0	10	8.0	19
14.5	10	7.5	20
14.0	10	7.0	22
13.5	11	6.5	25
13.0	11	5.5	30
12.5	11.5	0.5-5.0	2 days
12.0	11.5		

In practice light infection requires a period of at least 9 hours with relative humidity over 90 per cent. A 'near miss' period can occur when either the period is one hour too short, or 0.5°C too cool to satisfy the temperature/time criteria.

Barley Mildew

Two sets of criteria are used operationally. Conditions favourable for spore release occur when there is a:

- daily maximum temperature above 15.6°C
- sunshine > 5 hours. More recently this has been changed to an 0900 dew point depression more than 5°C
- daily rainfall less than 1 mm
- the highest of the four wind speeds measured at 00, 06, 12 or 18 GMT greater than 15 knots

The number of these conditions satisfied on a particular day gives the so-called 'Polley count'. A high-risk day is one on which one of the following are satisfied:

- a Polley count of 4
- 2 consecutive days with a count of 3
- 3 " " " " " " 2 provided that at least one of these days had a count of 3 or more

Alternatively the 'Smith index' S can be used:

$S = 3T + \frac{1}{2}W + H$

where T = maximum temperature (°C)
W = wind speed at 1200 GMT (knots)
H = hours of sunshine

A high-risk day is one on which S > 64.

Met 08a evaluates both sets of criteria daily.

Eyespot

Hourly temperature and relative humidity values are used to compute indices for sporulation (A1) and infection (B1) for, respectively, the first and second weeks of a 14-day period. Summation of these indices gives W1, daily values being calculated from the running two week total.

7-day running means of W1 give the daily infection probability values WD which can be plotted graphically to produce a smooth curve of infection probability. The curves can be used to predict likely disease development 6-8 weeks (one incubation period) in advance.

Net Blotch

There is a high risk of net blotch when all the following criteria are met during the period 0900-0900 GMT:

- Relative humidity (RH) ≥ 95 per cent for at least 5 consecutive hours
- " " ≥ 70 per cent for at least 17 hours (need not be consecutive)
- Minimum temperature ≥ 3.5°C

These criteria were first introduced on 1 January 1983 and are experimental.

Potato Blight

A wealth of literature has evolved over the years describing the various techniques for predicting the spread of potato blight. The recently introduced mathematical potato blight model has been explained in detail elsewhere and will not be reproduced here (see Sparks, 1980).

Rhynchosporium

Temperature °C	Hrs. of leaf surface wetness required for infection: Slight	Moderate (½ Max. potential infection)	Severe
(<6)	(>12)	(>18)	(>26)
7	11	16	22
8	10	15	20
9	10	14	19
10	9	13	18
11	8	12	16
12	8	12	16
13	7	11	15
14	7	10	14
15	6	10	14
16	6	9	13
17	5	9	13
18	5	8	12
19	4	8	11
20	4	7	11

NOTES: 1. If the week preceding an infection period has been predominantly dry with low relative humidities, then 12 hrs, should be added to the surface wetness durations in the above table to allow time for sporulation to occur.

2. The degree of infection resulting from a period of favourable weather will depend on inoculum levels within the crop and the susceptibility of the cultivar.

Septoria

Suggested criteria for spring and summer infection:-

a) Rain on 2 out of 3 days totalling at least 10 mm with rain on the first day.
b) Rain on 3 consecutive days totalling at least 5 mm.
c) Rain on 4 consecutive days.

A relative humidity of at least 90% (assumed equivalent to a dew point depression of 1°C or less) must be recorded at 0900 GMT on at least one day in each period.

OR

A period of 16 hours or more commencing with rain and continuing as long as there is precipitation or a dew point depression of 1°C or less with rainfall totalling at least 5 mm.

NOTES

1. The criteria used in the operational program is the latter except that no account is taken of the total rainfall amount; the plant pathologists apply this criteria themselves.

2. Wind speed during periods of leaf wetness may be important for the spread of septoria.

APPENDIX 2

A short extract from a typical HERDS message is shown below. (Note that potato blight indexes SM, SR, AIN were 'out of season' at this time.)

PLANT DISEASE INFECTION CRITERIA ON 21/05/1983

	APPLE SCAB	RHYNCHOSPORIUM			RAIN	09D	BARLEY MILDEW	EYE SPOT		POTATO BLIGHT MODEL			WET PERIODS TIME OF END	LEN HRS	MEAN TEMP DEG
STN NO	E	C	O	L	MM	D	SMTH	POL	WD	SM	SR	AIN	HRS	HRS	C
* LER005	/	R2	S	2	0.4	1.6	33.4	1		/	0	13.1	12	022	6.2
KIR017	/	R1	/	2 +	0.0	2.2	29.9	1		/	0	10.7	13	015	6.8
BEN022	/	/	/	2	0.3	2.2	34.7	1	56.3	/	0	11.2			
STO026	A	R3	S	1	1.9	0.4	29.5	0	96.0	/	0	11.9	18	025	6.8
KIN066	NM	R2	S	2	2.7	3.9	40.6	0	59.6	/	0	8.4	C	017	7.2
GLE070					2.3	3.3	40.2								
WIC075	/	/	/	3	0.1	1.9	28.3	1		/	0	10.3			
DYC091	/	R1	/	2	2.3	4.1	36.6	0		/	5	6.9	22	011	8.3
FRA093					1.1	2.0									
TIR100	/	/	/	2 +	0.0	3.5	41.4	2	92.2	/	0	18.4			
MCH111						0.0									
PRE135	/	/	/	1 +	0.0	4.3	49.6	1	51.9	/	0	7.6			
WHI137					0.0	4.7	51.3								
ABT140	/	/	/	2	1.8	2.8	45.7	0	62.2	/	0	6.2			
GLE147					14.7	3.2		0							

The full message contains data for over 100 stations of which 60 report hourly and have the full complement of disease indices. The locations of these stations are shown on the map.

Message Description

1. STN NO

This is the station identification code which has been limited to 6 characters, 3 for its name and 3 for WMO station number, to save space on the telex message (70 characters per line).

2. APPLE

The apple scab index. Any of the following symbols may appear:

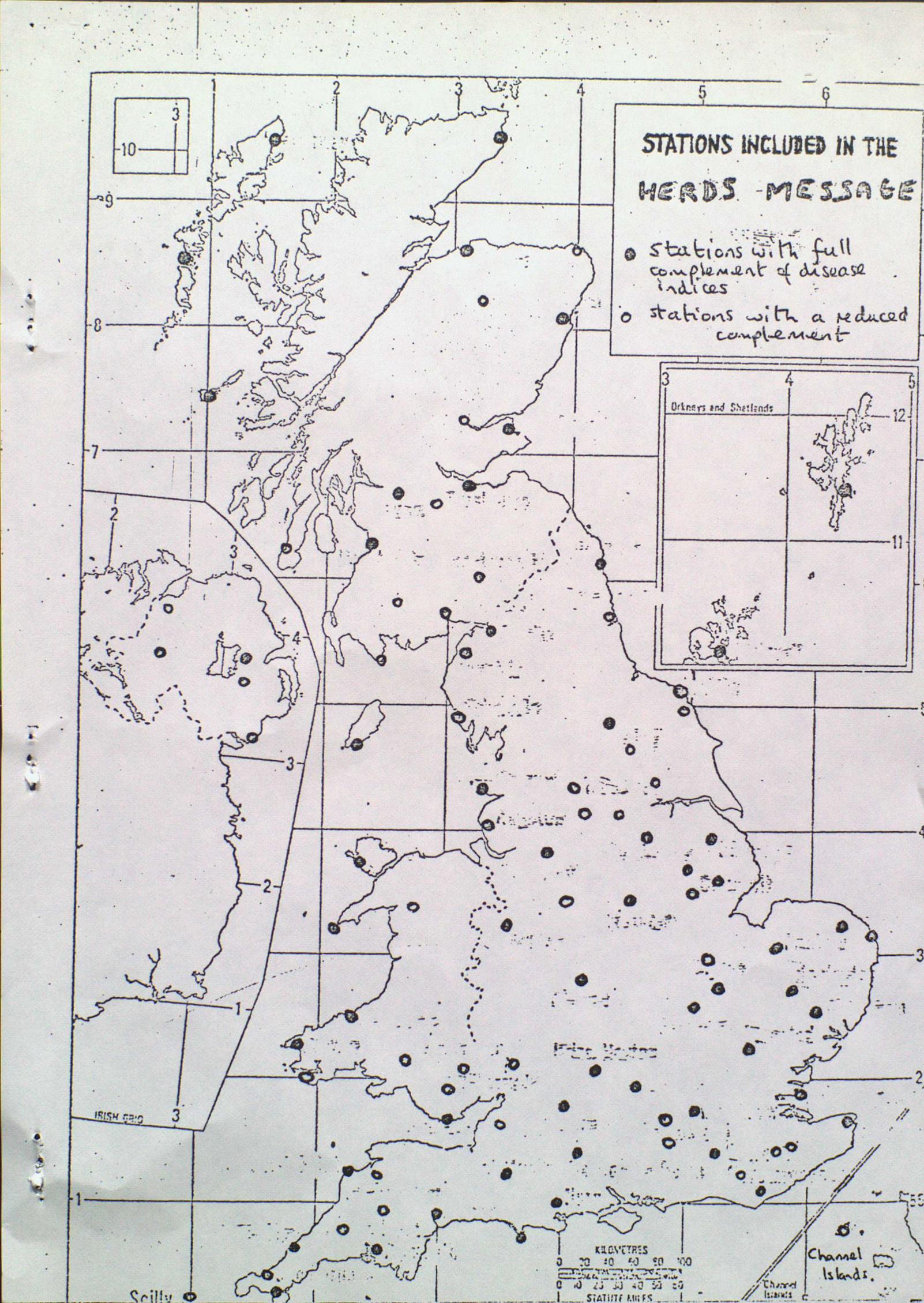
A - indicates that the requirements for at least light infection* have occurred.
NM - the criterion for light infection was not satisfied because the wet period (see below) was too short by one hour and/or too cool by 0.5°C.
/ - conditions unsuitable for infection.

'blank' - no index calculated because of one of the following reasons:
a) missing data
b) required data not reported by station
c) disease 'out of season'

3. RHYNC

The rhynchosporium index. Any of R1, R2, R3, / or 'blank' may appear. R1, R2 and R3 indicate that conditions suitable for slight, moderate or severe infection* occurred respectively. / and 'blank' take the same meaning as before.

* See Appendix 1 for relevant criteria


STATIONS INCLUDED IN THE
HERDS - MESSAGE
stations with full complement of disease indices
stations with a reduced complement
Orkneys and Shetlands
IRISH GRID
KILOMETRES
STATUTE MILES
Channel Islands
Scilly

4. SEPTO

The Septoria index, which can have the symbols, S, / or 'blank' appearing. S indicates the possibility of Septoria infection and is used by plant pathologists as an aid to the application of the wheat septoria infection criteria*. / and 'blank' remain as before.

5. NETBL

The net blotch index. A 0, 1, 2, 3 or 'blank' may appear, where '3' indicates a high risk of net blotch.

6. RAIN

The total rain, in mm, from 0900 GMT on the date of the message to 0900 GMT the following day. A 'blank' shows missing data while '+ 0.0' indicates a trace. (< 0.05 mm)

7. 09DPD

The 0900 GMT dew point depression, in degrees celsius, on the day of the message. A 'blank' indicates missing data.

8. BARLEY MILDEW

SMTH - The Smith index as calculated from the criteria in Appendix 1. A 'blank' indicates either missing data or index not calculated.

POL - The Polley count. A 'blank', 0, 1, 2 or 3* may appear. A 'blank' is as for SMTH.

9. EYESPOT

WD - the daily infection probability*. A 'blank' appearing has the same meaning as under APPLE.

10. POTATO BLIGHT MODEL

SM - the symbols P, NM, / or 'blank' may appear. The P indicates a 'half' smith period, ie at least 11 hours with relative humidity of 90 per cent or more and the minimum temperature at least 10°C. NM shows a near miss and / and 'blank' take the same meaning as under APPLE.

SR - an index of viable spore release from each active lesion.

AIN - a measure of the accumulated infection.

11. WET PERIODS

Certain plant diseases require a period of leaf wetness for part of their life cycle. The timing and duration of wet periods can be useful to a plant pathologist in predicting the likely importance of these diseases.

A wet-period is defined as starting with rain and continuing as long as there is precipitation or a dew point depression of 1°C or less (breaks of 1 hour are allowed in these conditions).

TIME OF END - the time of end of the wet period to the nearest hour. A '00' signifies a period ending at midnight and 'C' a period continuing into the next day's message.
LEN - Duration of wet period in hours.
MEAN TEMP - the average temperature for the period in degrees celsius.

A blank under any of the headings has the usual meaning.

* See Appendix 1 for relevant criteria.